

GALVANIC BATTERIES IN MEDICINE, WITH DESCRIPTION OF A NEW SELECTOR.

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IT will be necessary before entering upon a description of the selector, which in reality is the object of this communication, for the clearer comprehension of the instrument and its *modus operandi*, to make a few remarks about the proper battery to be employed in the application of galvanism to the human body. So much of the result obtained depends upon the battery itself that we are not at all surprised frequently to hear of negative results only having been obtained in many diseases of the nervous system, in which same disorders we are convinced that galvanism is beneficial. We have also occasionally heard complaints against the injurious effect of electricity in a given case, which statement was all the more surprising, because we have never, when properly applied and with the use of a proper battery, experienced any prejudicial effects from its use. Even Duchenne (of Boulogne), during a very long period of time, insisted upon the uselessness, the dangers, and the painfulness of the galvanic current. Even in the last edition of his work, "De l'Electrisation Localisée," we repeatedly find the idea expressed, that the constant current possesses the very serious fault of producing blisters and eschars. We know well that this ought not and does

never occur when a proper battery is used and proper precautions taken; therefore, why is it that so eminent an authority should have repeatedly made an assertion which is apparently incorrect? It was no error on the part of Duchenne; he really did experience these serious obstacles in the application of galvanism to the human body, and for the simple reason that he used a Bunsen battery for the production of his current,—a battery which at present is entirely discarded in medicine. This fact alone is sufficient to enable us to understand why he had so little confidence in the beneficial effects of this current.

In the selection of a battery there are several cardinal principles which must be borne in mind, and which must not for a moment be lost sight of :

- 1st. The internal resistance.
- 2d. The electromotor force of the cell.
- 3d. The capacity and durability.

These factors are governed by the following rules :

First.—The internal resistance decreases with an increase in the size of the electrodes, and increases with an increase of the distance between them. The internal resistance, also, depends to a great degree upon the specific conductivity of the fluid, for all fluids do not present an equal resistance to the current.

Second.—The electromotor force does not depend upon the size of the electrodes, but upon the materials of which the constituent parts of the battery are composed.

Third.—The durability of a battery depends directly upon its capacity. In general terms, then, the practical conclusion to be drawn from these propositions is: the larger the cell the less will be its internal resistance and the greater its durability. The question of polarization must not be neglected in the choice of a cell.

Many authors, especially the French, speak of the chem-

ical action of a cell—speaking of high or low chemical action—in reference to its effect upon the body. This term is a perplexing one, and one which should be discarded, as the expression “intensity” includes all that may be conveyed by the other term. The intensity of a battery is equal to the quotient of the electromotor force divided by the resistance, or $I = \frac{E.M.F.}{R}$, consequently a cell is more intense in its action the higher the electromotor force, and less intense the lower the resistance. Thus, for instance, if we take the resistance of a Daniell at 20 ohms, the intensity of ten such cells, considering the Daniell as a unit, will be $\frac{10}{200}$ or $\frac{1}{20}$. If, on the other hand, we take 10 bichromate-of-potash cells, freshly charged, the E. M. F. of each will be 2, and the resistance will vary between $\frac{1}{2}$ and 1 ohm, consequently the intensity of the bichromate-of-potash battery will be $\frac{20}{10} = 2$, or forty times as intense as the corresponding Daniell. Thus we see that what others are pleased to call high or low chemical action is nothing more than greater or lesser intensity; and, as it is directly dependent upon the E. M. F. and the resistance, it does not add another complicating factor to our choice of a battery.

It must not, however, be inferred from the above example that the difference between the two cells is so vast when the current from either is passed through the human body, which has a resistance of at least 2,000 ohms. With this modification the first case (Daniell) would read: $\frac{10}{200 \times 2000} = \frac{1}{20000}$, and the second (bichromate): $\frac{20}{10 \times 2000} = \frac{2}{2000}$ or only about as much again. There are so many different kinds of batteries in use that it will be advisable to describe only the five systems which are the most practical, and of those only the one battery which is generally considered the most serviceable for medical use:

(1) Cells with one fluid—Sulphuric-acid battery.

- (2) Cells with two fluids—Daniell battery.
- (3) Cells with the chlorides—Chloride of silver.
- (4) Cells with depolarizing mixtures—Bichromate of potash and sulphuric acid.
- (5) Cells with oxides—Peroxide of manganese.

SULPHURIC ACID BATTERY.

This is the simplest form of a voltaic cell and consists of a plate of copper and a plate of zinc, partially immersed in dilute sulphuric acid, which acts only upon the zinc. The polarization which takes place in these batteries is very strong.

DANIELL BATTERY.

The chemical action in this battery is as follows: The zinc is dissolved, forming sulphate of zinc, and the hydrogen which is developed is replaced by an equivalent amount of copper, which is deposited upon the copper electrode. The surface of the electrode being thus preserved intact, and no change occurring, no process of polarization can take place. To be concise, the addition of the sulphate of copper is sufficient for the depolarization of the negative electrode. As a direct consequence of this non-polarization, we would be justified in expecting to find the electromotor force of this battery an unchangeable one, and, indeed, experience proves that it is a battery of great constancy. This cell, by virtue of its constancy, has been accepted as a standard for comparison. The British Association has, however, accepted a "Volt" as their standard, which differs very little from that of a Daniell.

Change of temperature seems to have but very little influence upon the constancy of this battery. (Sabine.)

It changes very little with an increase or decrease of acid concentration. (Lattimer Clark, Sabine.)

It undergoes only very little change with a variation in the quantity of blue vitrol. (Jul. Regnault.)

Thus, considering all the above facts, we see that the electromotor force is almost constant. Nevertheless, experiments show that the intensity of the current is continually undergoing variations. The electromotor force being constant, as shown above, this change can only be due to a variation of resistance; and such is the fact. For various reasons the resistance is continually changing. There are very many modifications of this cell, but as they all possess pretty much the same characteristics it is unnecessary to further describe them.

BATTERIES WITH THE CHLORIDES.

Of this class the best one for medical use is the chloride-of-silver cell. In this the chemical action which takes place is the following: The zinc is dissolved and takes the place of the silver in the chloride. The silver is deposited in the form of a porous mass; at first only upon the surface, and then gradually permeating the entire substance. This battery presents one very great advantage—the same as that presented by batteries in which the chloride of ammonium is used—which is that as long as the circuit is not closed, there is no action upon the constituent parts of the battery.

CELLS WITH DEPOLARIZING MIXTURES.

Cells with bichromate of potassium and sulphuric acid.

These cells have a very high electromotor force, which is equal to 2,028 (Clark and Sabine)—double that of a Daniell.

This high electromotor force, however, only exists when they are first used, for the reason that the cells become polarized very rapidly, because the depolarizing mixture acts well only while it is fresh, and the substances, acting upon themselves even when the battery is not in use, soon lose their depolarizing action. These batteries, we know from a large experience with them, require constant care and supervision. Their constancy is continually under-

going variations, which, however, are not due to any appreciable diminution of the electromotor force, but to a very material increase in their resistance.

CELLS WITH THE OXIDES.

Peroxide of Manganese—Léclanché.

The chemical action which takes place in this battery is as follows: The zinc forms a combination with the chlorine of the chloride of ammonium, and forms chloride of zinc, and the ammonium is liberated. The freed hydrogen, which without the presence of the peroxide of manganese would polarize the carbon, is oxidized to water; the peroxide is reduced to sesquioxide of manganese, the ammonium is dissolved in the water and enters into a combination with the chloride of zinc. The advantages of this battery are the following:

(1) The zinc is not attacked by the ammonium salt, and therefore no action takes place when the circuit is open; or, to put it in other words, when no current is produced no consumption of material takes place. There can, therefore, as far as this point is concerned, be no question as to the superiority of this battery over the gravity.

(2) Owing to the depolarizing action of the peroxide of manganese the electromotor force of these cells is very high. It has been placed by Léclanché himself at 1.38, a Daniell taken as 1.00, but other authorities place the figures higher still, at 1.60 or more.

(3) The cell has a comparatively low resistance, which is due to the excellent conductive power of all the materials used in its construction and to the very large surface of the electrode. Cells having a porous cup of fourteen cm. in height have a resistance of $5\frac{1}{2}$ –6 ohms. In cells of equal calibre the resistance of a Léclanché is less than that of a Daniell.

(4) The cell does not contain any poisonous materials and does not generate any fumes or noticeable odor. There are several practical points in the use of this battery which materially aid its action and tend to preserve it from waste. They are: Keep the zincs well amalgamated, so that no irregularities or porosities appear upon its surface. Use pure sal ammoniac. Use a saturated solution. Only fill with fluid to one half the height of the porous cup. Never allow the battery to remain closed upon a short circuit. The depolarization which is produced by the peroxide of manganese is not complete when the external resistance is a small one, and consequently the electromotor force sinks very rapidly under this condition. It is a fact, and one which has been raised strenuously against the employment of this battery, that if the battery is closed upon a short circuit, a few minutes are sufficient to completely polarize it. This objection to its use is, however, not a valid one; for, firstly, the battery was not designed for use on a short circuit, and using it thus is endeavoring to make it subservient to ends for which it was never intended; secondly, if the current is interrupted it quickly regains its former strength. It recuperates very rapidly under repose. This is the question of polarization in all its simplicity. This battery requires no attention for a long period of time. We have had these cells in use for over a year without giving them the slightest attention; at the end of that time it was, perhaps, necessary to add some water, in order to replace the amount which had been lost through evaporation, or, if the battery had been excessively used, to replace some of the zincs. With these slight exceptions we have not been obliged to have any thing done to the battery for upward of three years, and this under daily usage and for protracted periods of time. It would here not be out of place to impress upon our readers the fact that such satisfactory service can only

be obtained by proper care, or, to express ourselves more correctly, by an absence of improper care. Meddlesome interferences should be entirely avoided, and no person except one accustomed to its care should attempt to repair a disordered battery. We have frequently seen inexperienced operators shake the battery, with the idea of thereby increasing its strength, when told by the patients that they did not feel the current. That this is an error, and certainly prejudicial to the battery, we need not insist upon.

The Léclanché battery has also been arranged in a portable form, as follows: A test-tube, having a platinum wire which reaches to one third the height of the tube embedded in the bottom, is filled to this same height with granular peroxide and carbon, and upon this is poured a saturated solution of chloride of ammonium. An amalgamated stick of zinc, passing through a rubber stopper which closes the tube, forms the other electrode.

The objection to these small cells is that their capacity being reduced to a minimum, they are very easily and quickly exhausted, and must then be refilled, which is a somewhat troublesome operation.

In general terms, then, the choice of a battery for the application of the continuous current should be governed only by the source whence the electricity is obtained, all other questions of portability, appearance, etc., are only secondary questions and subsidiary to it. In ordinary cases of peripheral disease of the nervous system this necessity is not so great and almost any battery will do, but for central lesions and in the more delicate operations on the head, eye, or ear, or, in brief, where the regularity of the current is of supreme importance, it is an absolute necessity to have a battery of—

1. Low intensity.

2. Great constancy.

As regards the inconveniences of too great intensity they are the following: The sensation of burning and the disorganization of the skin are produced very rapidly. The currents generated by such batteries are always more or less irritating and produce general excitation. On this account the cells which contain the bichromate mixture are not commendable. Furthermore, when a current from such a battery is applied to the head, the change from cell to cell is a decided one and may become dangerous. For instance:

$$I = \frac{E.M.F.}{R} \quad \frac{E.M.F.}{R} \text{ of a Léclanché} = \frac{1.5}{\frac{1}{2}} = \frac{1.5}{\frac{1}{2}} = \frac{3}{1} \text{ I.}$$

$$\frac{E.M.F.}{R} \text{ of a bichromate} = \frac{3}{1} = 3 \text{ I.}$$

i. e., the intensity of a bichromate of potash cell is six times as high as that of a Léclanché.

The current, when the external resistance is low, and this is always reduced by the prolonged passage of the current, is much more felt; especially is this the case in a freshly charged bichromate cell, and also to a lesser degree in a freshly charged Léclanché. At the same time the amount of electricity passed is very small. This point is one of importance, because batteries are frequently selected precisely for this quality we now condemn. This selection is made with the idea that the thermic action of the battery upon the skin is a gauge of the quantity of electricity generated. This question of intensity, in our estimation, far outweighs all questions of constancy, and if we have our choice between two batteries, the one of great intensity and great constancy, and the other of low intensity and great inconstancy, we would under all circumstances prefer the latter.

This selection would, however, also be influenced by the well-known fact in physics, that the slower the decomposition in a cell takes place the more perfect is the arrest of

polarization, and therefore the greater the constancy. The process of decomposition can be easily retarded by placing a very high resistance in the circuit, and thus when a current from a comparatively inconstant battery is passed through the human body, the resistance of which is very high, varying from 1,500 to 10,000 ohms, the battery becomes for the time being practically constant. It is probably in consideration of this fact that many eminent authorities, and among them Erb, use a battery which is in itself an inconstant one.

To sum up, then, if a portable battery is desired, the chloride of silver is the one that we would recommend, its only objection being its high cost. The bichromate-of-potash battery should be classed as ranking last in the scale of commendable batteries. The ordinary gravity batteries and the Léclanché are the only two batteries that we can unhesitatingly recommend. They are, however, necessarily stationary. The Daniell is, as we before remarked, very constant, and is from all theoretical points of view the nearest approach to a perfect battery, but its bulk is so great and the constant care which it requires is such that none but a specialist can devote the necessary attention for its proper maintenance. In view of this we consider it practically inferior to the Léclanché battery, for, as has been shown above, the inconstancy of the latter does not come into action. We have now used the Léclanché cells for a number of years and have been in every way satisfied with them; the only trouble that we have experienced during their use was owing to the fact of the first few cells of the battery becoming used up much sooner than those further on in the series. This, however, was not due to any fault in the battery but to the imperfection of the current selectors now in use. For this reason we have devised a selector which has now been in use on several batteries for over

a year, and which leaves nothing to be desired as regards its practical utility.

The selector, or, as Zech calls it, the "element counter," is an apparatus which is generally considered essential to the proper application of galvanism in medicine. By means of this instrument we are enabled to bring into action any number of cells from first to last, and therefore can increase or diminish the strength of the current as necessity may require. A perfect selector should allow of the gradual increase or decrease in the strength of the passing current without producing any interruption of its steady flow. It should make an absolutely close connection of the voltaic chain, and finally should permit of a selection of the cells from any part of the circuit—commencement, middle, or end. In order to be able to clearly comprehend the advantages which our selector possesses, it will be necessary to briefly describe the principles upon which those act which are now in use. They are constructed according to one of three models—the crank, the rider, and the plug, systems. The selector which has, until now, been considered the most practical, is that described by Remak. It consists of a plate of hard rubber, upon which are arranged in a circle or semicircle the metallic buttons through which the connection is made. A metal crank, pivoting at the centre of the circle, can be brought into contact with each of the buttons successively, thus allowing a current of more or less intensity to pass according to the button upon which it rests.

By this means we are obliged to take the buttons with their corresponding cells in rotation, beginning at the first. The result of this is, that the first cells, by constant usage, become rapidly weakened, while the last ones remain almost unused. Thus is produced an irregularity of the current which is very unpleasant and may, under circum-

stances, become injurious. This objection has been obviated by Gaiffe. His selector is, however, too complicated to be described in this connection. It also presents one objection, which all the selectors of the crank variety do,—namely, that the connection between crank and button is very apt to become loosened, and thus a break in the current liable to occur.

The second class of selectors are those known as the plug or “Brenner’s” selector. This differs from the crank selector inasmuch as, instead of buttons and a crank, brass plates and plugs are used. Each metallic plate has a semi-circular piece cut out at either end, so that, when the ends of two different plates are approximated, a circle is formed, into which the metallic plug fits tightly. This plug selector is very rarely used now ; its disadvantages are apparent.

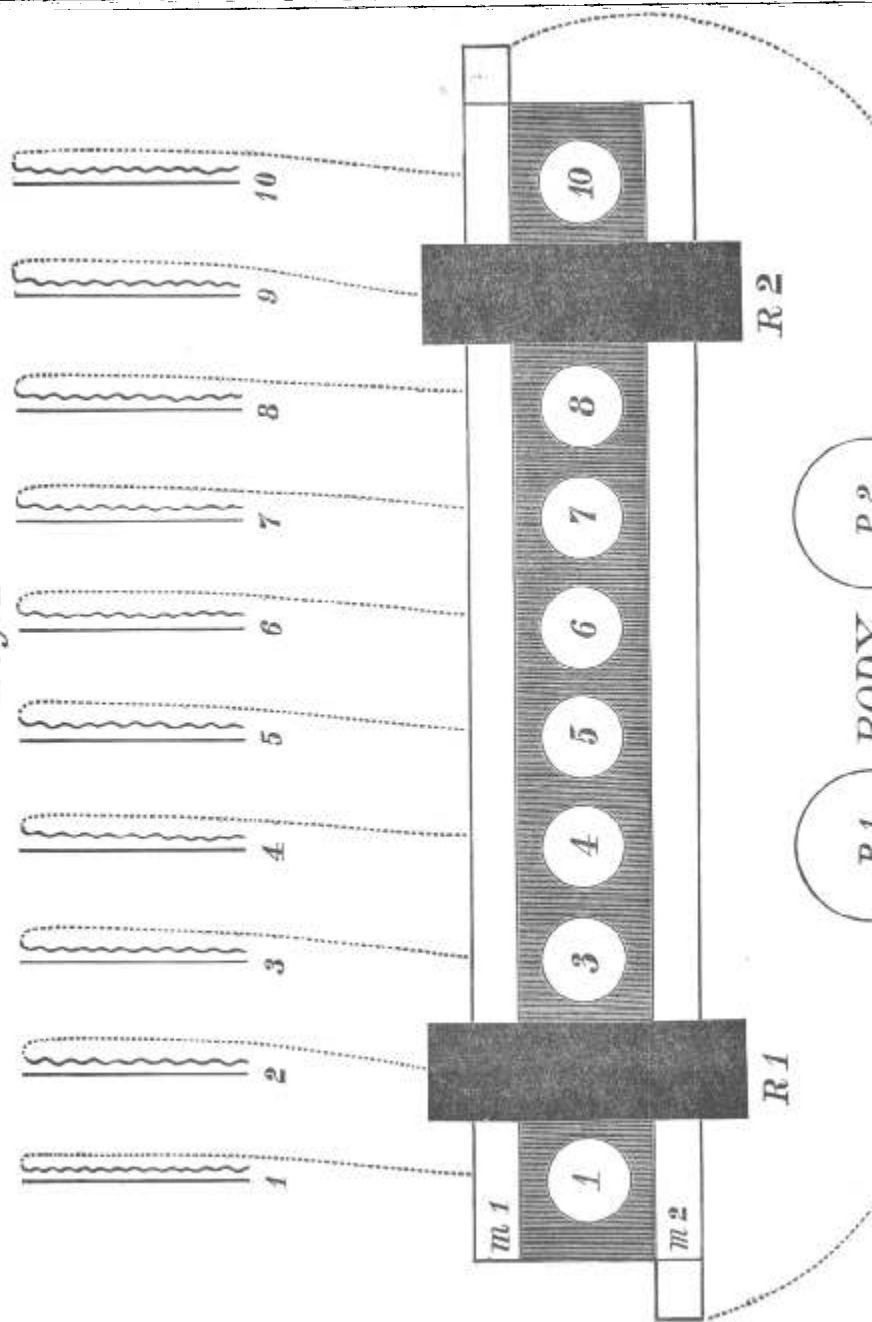
The third class of selector may fairly be represented by that of Stöhrer. It consists of a rectangular strip (table) placed horizontally upon a base. Along both edges of the former are fastened, at regular intervals, plates of brass which correspond to a certain number of cells. A metallic rider is placed over the median portion and is movable between the two rows of plates forming a metallic contact with them. If the rider is placed at O, no current passes ; if at the point 2, two cells are brought into action, and thus, the farther the rider is removed from O, the stronger the current. These last two systems have the same disadvantage as the first,—that of using up the first cells before the rest. By means of the rider system, cells cannot be introduced singly but only in pairs.

The selector¹ to which we hereby desire to attract attention is a combination of all three systems, at the same time partaking more of the characteristics of the rider variety. Upon the base of the battery is attached a strip of hard

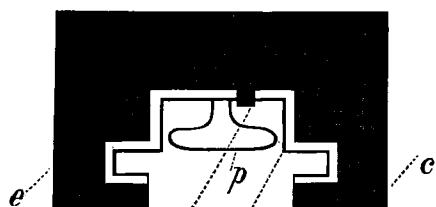
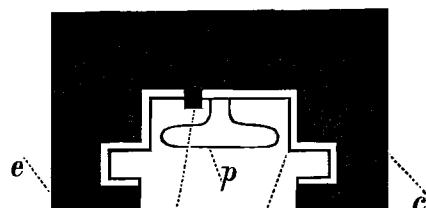
¹ This selector is manufactured by W. Weihl, model-maker, 332 Seventh Avenue.

rubber, which is surmounted by as many buttons as there are cells in the battery (see illustration for ten cells). Two strips of metal run along the sides of the rubber strip from end to end (fig. 1, *m* 1, *m* 2). Two riders easily movable toward either end surmount this (fig. 1, R 1, R 2). These riders consist of a hard-rubber body, which serves as a handle, to the bottom of which is attached, by means of a strong spring, a metallic plate, once and a half as large as a button (fig. 2, *p*, *p*). The whole rider is kept in place by two side pieces, best described as clamps (fig. 2, *c*, *c*, *c*, *c*), which are in close connection with the metallic strips *m* 1, *m* 2, fig. 1. This entire rider is lined by a thin plate of metal, so that a direct metallic connection is formed between it and the metallic strips (fig. 1, *m* 1, *m* 2). The metal lining of the upper clamp of the left-hand rider is broken (fig. 2, *br* 1) the lower clamp of the right-hand rider is also broken (fig. 2, *br* 2). The connections then are as follows: The lower metallic strip (fig. 1, *m* 2) is connected to the binding-post on the left hand. The upper metallic strip (fig. 1, *m* 1) is connected to the right-hand binding-post. The zincs of each cell are connected to the buttons with corresponding numbers. The cells are connected among themselves in series, the zinc of No. 1 to the carbon of No. 2, etc. Upon whichever buttons the riders may be placed, all the cells contained between them are brought into action, and the cells lying exteriorly of either rider are thrown out. The following example will make this clear, and plainly demonstrate the *modus operandi* of the selector. If the rider R 1 is placed upon button 2, and rider R 2 upon button 9, we will have seven cells in action, and the current passes from the second cell to the second button, from this button into the first rider (R 1), which is placed upon it. The connection of the rider with the upper metallic strip being broken, it goes to the lower metallic

Fig. 1



strip, and thence through the connecting wire to the binding-post (P 1). From there it passes through the body connecting the two posts to the second binding-post (P 2), through the wire to the upper metallic strip, along this to

*Fig. 2**R 1.**Br 1.**m1**R 2.**Br 2.**m2*

rider 2, and then into button 9, upon which it rests, through the wire to the battery, thus completing the circuit. The advantages which we claim for this selector are:

1st. There is always a firm connection between the buttons and the riders. This being accomplished by means of a spring, the button is forced down upon the button of the selector from above.

2d. The cells can be introduced into the circuit one by one, and not as in other instruments of the rider variety, only in pairs.

3d. The first cells of the battery do not become worn before the others. Whatever may be the position of the riders, the only cells comprised in the circuit are those situated between the two riders, and all cells situated this side of the first rider, or the other side of the second rider, form series of isolated cells.

4th. It is very simple by means of this selector to detect any break that may have occurred; for if the riders are approximated and moved along the selector, the cells are taken singly and in rotation, and the galvanometer will at once indicate the site of the break.